A MULTIPLE REGRESSION APPROACH FOR THE ANALYSIS OF BIOMECHANICAL PARAMETERS AS PREDICTORS OF SPIN BOWLING IN CRICKET

SHORT SYNOPSIS

Submitted in partial fulfilment of the requirement of the degree of

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CERTIFICATE

I hereby declare that the short synopsis **"A Multiple Regression Approach for the Analysis of Biomechanical Parameters as Predictors of Spin Bowling in Cricket"** being submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in Physical Education under faculty of Lakshmibai National Institute of Physical Education, NERC, Guwahati, Assam during the academic year 2021-22.

It is Bonafide record of original work carried out under the supervision of Dr. Hem Chandra Joshi and has not been submitted in full or part to any other university or institute for a degree or diploma. Further it is certified that the short Synopsis is plagiarism-free and the proof has been submitted.

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Abstract

The present study aims to biomechanically analyze the phases of spin bowling and to determine the influence of selected kinematic variables on bowling accuracy among under-19 women cricketers. A sample of thirty right-handed off-spin bowlers from various divisions of Madhya Pradesh was selected using purposive sampling. The spin bowling action was divided into six critical phases: run-up, back foot contact, front foot contact, cradle position, ball release, and follow-through. Two-dimensional motion analysis was employed using Kinovea software, supported by the use of radar guns and grip dynamometers to assess both linear and angular kinematic parameters. Key variables measured included center of gravity in each bowling phase, ball speed, ball release height, Joint angles, grip strength, and head positioning.

Bowling accuracy was evaluated using the Richard Aldworth Stretch Bowling Test. The importance of biomechanics in sports performance is well recognized, particularly in skill-based disciplines such as spin bowling, where precision, balance, and fine motor control are prioritized over raw speed. Although women's cricket is growing rapidly in India, there is a lack of in-depth biomechanical studies focusing on women spin bowlers, especially in the under-19 category. By addressing this research gap, the study seeks to identify specific biomechanical factors that directly influence bowling accuracy, thereby providing scientific guidance for player development and coaching interventions.

The findings of this study are expected to assist coaches in designing evidence-based training programs, support athletes in self-assessment and performance enhancement, and contribute to talent identification strategies. It is hypothesized that the selected kinematic variables have a significant correlation with bowling accuracy during the different phases of spin bowling.

Keywords: Spin Bowling, Biomechanics, Kinematic Analysis, Bowling Accuracy, Women Cricketers, Motion Analysis, Talent Identification, Sports Performance

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1 INTRODUCTION

Cricket, one of the most widely played and followed sports globally, has seen considerable evolution in terms of both its playing style and technological advancements. The increasing complexity of the game has given rise to a deeper understanding of the biomechanics that underpin performance, particularly in disciplines like spin bowling. In cricket, spin bowlers play a crucial role, utilizing wrist or finger spin to deceive the batsman and create opportunities for dismissals. Spin bowling requires a high level of skill and technique, as it involves precise manipulation of the ball to generate the desired spin and trajectory. As such, the biomechanics of spin bowling, which is a blend of complex kinematic motions, plays a vital role in shaping the performance outcomes of the player.

One of the challenges in cricket biomechanics is understanding the exact movement patterns that differentiate a successful spin bowler from an ineffective one. Various biomechanical variables such as joint angles, angular velocities, release height, ball speed, and follow-through dynamics contribute to the overall effectiveness of a bowler. Additionally, the ability to maintain accuracy while executing these movements is crucial for achieving the desired outcomes in terms of both spin and control. The study of biomechanics in spin bowling has been relatively under-explored, particularly in the context of female athletes. Most research in cricket biomechanics has focused on fast bowling, with much less attention given to spin bowling, especially in the case of female players.

Biomechanics of Spin Bowling: An Overview

Biomechanics refers to the application of mechanical principles to biological systems, aiming to understand how forces are produced and transmitted through the body during sporting activities. The role of biomechanics in cricket, especially in bowling, has garnered attention from scholars and sports scientists alike (Hodges & Williams, 2017). Several studies have established that cricket bowling, particularly spin bowling, involves a multi-phase sequence of coordinated body movements, including the run-up, the delivery stride, and the follow-through (Lloyd & Oliver, 2009). Each phase of the bowling action is crucial for achieving optimal ball release and spin.

Spin bowling is fundamentally different from fast bowling in that it requires a more controlled and deliberate action to impart spin to the ball. Research by Bartlett et al. (1996) indicated that the efficiency of spin is largely influenced by the wrist and finger action, as well as the rotational forces generated during the bowling action. The accuracy of the spin also depends on the stability of the body's posture, joint positioning, and the synchronization between the upper and lower limbs (Hughes & Read, 2003). Furthermore, joint angles, angular velocities, and the release height of the ball are key kinematic variables that impact the effectiveness of spin bowling (Cohen et al., 2005). Understanding how these variables correlate with accuracy and control is crucial in improving performance.

Women's Cricket and the Need for Focus on Biomechanics

Historically, women's cricket has received less attention in terms of research and development compared to the men's game. However, with the growing popularity of women's cricket, particularly following the successes of the Indian women's cricket team in global tournaments, there has been a greater push for research and development in this domain. Women's cricket has evolved significantly, with increasing participation and the emergence of world-class female cricketers who have made their mark in international competitions (Bhardwaj, 2017). Yet, despite these advancements, there remains a notable gap in the scientific understanding of the biomechanics of women cricketers, especially in relation to spin bowling.

While several studies have focused on the biomechanics of fast bowling in both men and women (Folland & Allen, 2013), the study of spin bowling in female athletes has remained relatively underexplored. The existing literature primarily highlights the need for more detailed biomechanical analyses that consider gender-specific factors, including differences in physical strength, flexibility, and motion patterns (Thompson et al., 2014). As women cricketers increasingly participate in professional tournaments, understanding the biomechanical principles that contribute to their performance becomes essential in improving their technique and outcomes. Furthermore, as cricket becomes more inclusive, addressing the biomechanics of spin bowling in female athletes can provide valuable insights into coaching, talent identification, and injury prevention (Hogg & Roberts, 2021).

Biomechanical Considerations in Under-19 Women Cricketers

The under-19 category is a crucial developmental phase for cricketers, particularly for women who are transitioning into professional cricket. At this stage, athletes undergo significant physical and technical changes, and their skills and fitness levels are refined to meet the demands of higher-level competition. It is in this period that biomechanical interventions can be most effective in helping players optimize their bowling techniques. However, there is a lack of detailed studies examining the kinematic characteristics of under-19 women cricketers, particularly in the context of spin bowling.

The differences in biomechanics between adolescent male and female cricketers have been acknowledged in previous studies (Greenwood & Gabbett, 2019). Studies have shown that females tend to exhibit different kinetic patterns due to differences in strength, flexibility, and body composition (Ainsworth et al., 2009). These differences are crucial when assessing the biomechanics of spin bowling, as they may affect the generation of spin and the accuracy of the delivery. Given the gap in the current literature, this research aims to focus on the biomechanical analysis of spin bowling in under-19 female cricketers to identify key kinematic factors that influence bowling accuracy.

In conclusion, the biomechanics of spin bowling in cricket is a critical area of study that has received limited attention in the context of female athletes. This research aims to fill this gap by focusing on the under-19 category, a crucial phase in the development of cricketers. By examining the key kinematic variables involved in spin bowling and their relationship with bowling accuracy, this study seeks to provide a comprehensive understanding of the biomechanical factors that influence performance. The outcomes of this research will not only advance the knowledge of biomechanics in women's cricket but also offer practical applications in training, talent development, and performance optimization.

2 LITERATURE REVIEW

Kumar, Singh, and Sharma (2023) conducted a study that focused on the biomechanical impact of excessive knee flexion during fast bowling. The research showed that greater knee flexion at the front foot contact significantly improved the bowler's ball release speed but also increased the risk of knee injuries. They suggested modifications to technique to balance performance with injury prevention.

Mehta et al. (2022) conducted a study examining the relationship between trunk rotation and bowling speed in fast bowlers, highlighting the critical role of core stability and rotational dynamics in optimizing performance. The study found that faster bowlers exhibited a higher degree of trunk rotation, which facilitated more efficient energy transfer from the lower body to the upper body. This efficient energy transfer resulted in faster ball deliveries. The findings suggest that improving trunk rotation and core strength can significantly enhance bowling speed, offering valuable insights for coaches and athletes aiming to optimize fast bowling performance and reduce injury risks.

Verma et al. (2020) conducted a comprehensive analysis of the biomechanics of spin bowling. The study demonstrated that spin bowlers who maintained a consistent wrist position at the time of ball release could generate more consistent spin and achieve greater accuracy. The study used 3D motion capture systems to analyze the wrist and elbow angles during delivery.

Singh and Garg (2020) investigated the role of foot positioning in preventing injuries among young fast bowlers. The study concluded that improper foot placement during delivery could lead to an increased risk of lower back and knee injuries. Their findings emphasized the need for bowlers to focus on proper biomechanics of foot placement during training.

Bedi et al. (2020) performed an analysis on the effectiveness of wearable devices in measuring the biomechanics of cricket bowlers. Their research highlighted that smart wearables could help monitor real-time metrics such as wrist speed, arm angles, and shoulder load, aiding coaches in giving better feedback and injury prevention strategies for fast bowlers.

Harwood (2017) explored the biomechanics of young bowlers who often struggle with adapting to longer pitches. The study found that junior seam bowlers had to release the ball almost horizontally to achieve the necessary distance, compared to adult bowlers who typically

release the ball 7° below horizontal. The research indicated that when the bowlers bowled on a 16-yard pitch, the ball release angle was 3.4° lower than when they bowled on a 19-yard pitch, with no significant changes in ball speed. Harwood concluded that maintaining ball speed while bowling on longer pitches is crucial for bowlers to enhance their technique and success.

Felton (2017) conducted a study focusing on the knee angles of 20 elite fast bowlers during their bowling actions. The results showed that the back knee angle at back foot contact (BFC) was 149.4 ± 11.10° for male bowlers and 148.3 ± 11.60° for female bowlers. The study indicated that variations in knee angle could influence the biomechanics of the bowling action, directly affecting the performance of elite fast bowlers.

Goswami (2016) examined the biomechanics of spin bowling by analyzing five interuniversity-level leg-spin bowlers. The study utilized three-dimensional video analysis to evaluate the correlation between key biomechanical variables and bowling performance. Goswami found significant relationships between the angle of release, elbow joint position, and shoulder joint movements. The regression model constructed during this study accounted for 94.5% of the variability in lateral deviation of the ball, which is critical for spin bowlers in achieving better accuracy and performance.

Mondal (2016) provided a review of cricket team composition and the biomechanical factors affecting bowling performance. His study critically appraised the biomechanics of fast bowling, highlighting the importance of horizontal velocity, delivery stride length, and shoulder counter-rotation in achieving higher ball release speeds. The review emphasized that biomechanics plays a direct role in bowling efficiency, with technique optimization leading to better performance outcomes for bowlers.

Olivier (2015) conducted a study to investigate the knee mechanics and their relationship to injury and bowling performance in fast bowlers. The research followed 31 pace bowlers over a cricket season, analyzing kinematic data and knee angle variations. The study found that bowlers who remained injury-free throughout the season had greater knee flexion at the start of the season (157.07°) compared to the end (163.95°). The study indicated that knee angle variations might influence both ball release speed and injury rates, suggesting that bowlers should focus on optimizing knee flexion to prevent injuries while maintaining high ball speeds.

Worthington (2010) conducted a detailed analysis of the full-body mechanics and ground reaction forces in fast bowling. Using a 3D motion analysis system and force plates, the study assessed the interaction between bowling technique, ball release speed, and ground reaction forces. The study found that faster bowlers exhibited a more efficient run-up and straighter front knee during the front foot contact phase, with larger amounts of body flexion between front foot contact and ball release. These biomechanical aspects contributed to faster ball release speeds and reduced peak forces on the lower back.

Khangure (2002) conducted an intervention study on 41 young bowlers to assess the impact of coaching on developing front-on and side-on bowling techniques. The study found that

reducing shoulder counter-rotation during the bowling action led to a decrease in lumbar disc degeneration, suggesting that smoother techniques could result in better performance and less injury.

Portus (2000) investigated the relationship between front knee extension and ball release speed. The study found that bowlers who extended their front knee during front foot contact released the ball faster than those who did not. This finding reinforced the importance of knee angle in the biomechanical efficiency of fast bowling.

Burden and Bartlett (1990) studied the kinematics of the fast bowling action, specifically focusing on the relationship between knee angle at release and ball release speed. They found a significant correlation between the knee extension at front foot contact and higher release speed, further emphasizing the role of lower extremity mechanics in fast bowling performance.

Glazier (2000) examined the relationship between anthropometric and kinematic variables and ball release speed in fast-medium bowlers. The study found a significant correlation between horizontal velocity during the pre-delivery stride and ball release speed, with bowlers who generated more horizontal velocity achieving higher release speeds. The study also highlighted the importance of arm length and shoulder-to-wrist length in contributing to ball release speed.

Williams (2001) studied the kinematic differences in runners with high and low arches, which may provide insights into lower extremity mechanics that could be relevant to fast bowlers. The study found that runners with low arches exhibited increased rear foot eversion and tibial internal rotation, which could inform the understanding of lower limb mechanics in bowlers, especially in terms of injury prevention and performance.

Perell (2000) investigated the influence of force symmetry feedback training on pedal response power in individuals recovering from cerebrovascular accidents. While the study was not directly related to cricket, it offered insights into how feedback mechanisms could improve motor performance, which could be useful for coaching interventions in cricket bowling techniques.

Kerwin (1999) examined the effects of heel lift manipulation on lower extremity kinematics in running. The findings, while primarily focused on running mechanics, suggest that adjustments in footwear or body alignment could influence joint angles and strain. These insights may help in the development of optimized bowling footwear or adjustments in the bowling stance to reduce injury risks.

Foster (1989) and **Elliott & Others (1992)** conducted studies examining the relationship between ball release height and lower back injuries in bowlers. They found that higher ball release points were associated with an increased risk of stress fractures. This finding is significant for understanding how the height of release, delivery stride length, and knee angle at release could affect both the performance and injury rates in fast bowlers.

3 DESCRIPTION OF BROAD AREA

Biomechanics

Biomechanics is the scientific study of the internal and external forces acting on the human body and the effects of these forces on movement (Physiopedia, 2019). It involves understanding how muscles, bones, tendons, and ligaments interact to produce motion. As a subset of kinesiology, biomechanics focuses on the mechanics of movement, serving both as an applied science and a research domain to explore and implement the findings in practical scenarios (Rogers, 2019).

Kinematics

Kinematics is a branch of biomechanics that describes the motion of bodies, including aspects such as distance, speed, and movement consistency, without considering the causes behind the motion (Danica, 2018).

Linear Kinematics

Linear kinematics involves the study of linear movement over time, focusing on shape, form, pattern, and sequencing without considering the forces involved. It addresses aspects like displacement, velocity, and acceleration, offering insights into the mechanics of straight-line motion, which is critical for improving technique and performance in various physical activities (Hay, 1993).

Angular Kinematics

Angular kinematics is concerned with the rotational motion or angular movement of the body, focusing on the kinematic quantities used to describe this motion. It does not study the causes of angular movement but plays a vital role in understanding rotational dynamics (Hay, 1993).

Centre of Gravity

The center of gravity (COG) refers to a hypothetical point where the body's mass is concentrated, around which the force of gravity appears to act. The COG does not always lie within the physical boundaries of an object or person, but it can be estimated by balancing the body on a single point (Contributors, 2017).

Spin Bowling

Spin bowling in cricket is a specialized skill that requires a combination of technical expertise and strategic thinking. Spin bowlers use variations in wrist and finger movements to impart spin on the ball, causing it to deviate in different directions after pitching. Off-spin and leg-spin are the two primary types of spin bowling, with off-spin being characterized by clockwise rotation, which turns the ball away from a right-handed batsman. A bowler’s grip, wrist position, and the angle at which the ball is released all play a vital role in determining the amount of spin generated. Spin bowling is not just about generating spin, but also about creating deception, forcing the batsman to misread the ball and induce errors. Mastery of the technique involves understanding the physics of the ball's behavior and exploiting the pitch conditions for optimal turn and bounce (Jenkins, 2017). In addition to spinning the ball, a

bowler must vary the trajectory, speed, and length of deliveries to keep the batsman guessing, making spin bowling an art as much as it is a science.

Accuracy in Spin Bowling

Accuracy in spin bowling is crucial for its effectiveness, as it allows the bowler to consistently land the ball in the right areas, thereby building pressure on the batsman. For off-spin bowlers, accuracy involves landing the ball in key areas, typically outside the off-stump, forcing the batsman into risky shots. Precision in line and length not only maximizes the likelihood of dismissals but also facilitates the bowler's control over the game. The ability to consistently bowl to the right areas allows the bowler to exploit the conditions of the pitch, adjusting for turn and bounce. A bowler with good accuracy can also adjust their pace and flight, manipulating the ball's behavior to induce mistakes from the batsman. Moreover, accuracy in spin bowling involves understanding the batter's weaknesses and setting up deliveries to target specific areas or deceive the batsman with variation. Consistent practice, along with an in-depth analysis of performance, enhances accuracy, ensuring that the bowler can strategically exploit various pitch conditions and increase their chances of success (Smith, 2018; Thompson, 2019).

Off-Spin Bowling

Off-spin bowling in cricket combines precise technical execution with strategic planning. The primary aim is to impart clockwise rotation on the ball, causing it to turn away from a right-handed batsman. The key to successful off-spin lies in mastering grip, wrist flick, and ball release (Jenkins, 2017). Bowlers must focus on accuracy to consistently land the ball in the correct areas, putting pressure on the batsman and forcing errors. Understanding pitch conditions is crucial for adjusting the delivery to exploit the surface's impact on ball movement, further enhancing the bowler's performance (Smith, 2018; Thompson, 2019).

Six Phases of Off-Spin Bowling

Run-Up Phase

Description: The run-up is the bowler's approach to the crease, starting from a stationary position and ending when the back foot lands on the pitch.

Purpose: The run-up helps build momentum, enabling the bowler to generate speed and rhythm, which are transferred into the ball. The speed and length of the run-up depend on the type of bowler.

Back Foot Landing Phase

Description: This phase occurs when the back foot lands on the pitch, providing a stabilizing base for the bowler.

Purpose: The back foot landing sets the foundation for the delivery stride, transferring energy from the run-up into the bowling action. Proper alignment is essential for accuracy and injury prevention.

Front Foot Landing Phase

Description: The front foot lands on the pitch just before or as the ball is released, and the bowler's weight shifts onto it.
Purpose: This phase is crucial for generating power and controlling the ball. Proper alignment and stability during front foot landing ensure a controlled release and good timing.

Cradle Position
Description: The bowler's arm reaches its highest point, with the ball held securely in the hand, and the wrist is cocked back, ready to snap forward.
Purpose: This position prepares the bowler for the ball release. The hand and wrist position here are key in determining the type of delivery (e.g., seam, swing, or spin).

Release Phase
Description: The ball is released from the bowler's hand, with the wrist and fingers playing a crucial role in imparting speed, spin, or seam movement.
Purpose: This phase is where all the energy from the run-up and earlier phases is transferred into the ball. Precision in release timing and hand positioning is critical for achieving the desired ball trajectory.

Follow-Through
Description: After the ball is released, the bowler's body continues forward as part of the natural momentum.
Purpose: The follow-through helps maintain balance and minimizes injury risk. It also positions the bowler for potential fielding duties and ensures consistency in line and length.

Richard Aldworth Bowling Test
The Richard Aldworth Bowling Test for accuracy is a practical assessment designed to measure the precision and consistency of a bowler's delivery. It evaluates a bowler's ability to consistently land the ball in a specific target area, such as a designated line or length, over a series of deliveries. This test emphasizes the bowler's control over line, length, and trajectory, which are critical components of effective bowling in cricket. The ability to repeatedly hit a target area under different conditions is a key indicator of a bowler's accuracy and is essential for building pressure on the batsman. The Richard Aldworth Bowling Test provides valuable insights into a bowler's technical skill, mental focus, and ability to execute deliveries with precision, all of which contribute to success in match situations.

4 OBJECTIVES OF THE STUDY

PROBLEM STATEMENT

The researcher aims to conduct a comprehensive biomechanical analysis of the various phases of spin bowling, focusing on identifying the key factors that contribute to accuracy and efficiency in the delivery. By examining the mechanics involved in each phase—from the run-up to the follow-through—the study seeks to uncover the specific elements, such as body alignment, arm motion, wrist position, and release technique, that enhance a bowler's precision and overall performance.

RESEARCH OBJECTIVES

1. Biomechanically analyze run up phase just before the pre delivery phase of spin bowling.
2. Biomechanically analyze the back foot phase of spin bowling.
3. Biomechanically analyze the front foot phase of spin bowling.
4. Biomechanically analyze the cradle position phase of spin bowling.
5. Biomechanically analyze the release phase of spin bowling.
6. Biomechanically analyze the follow through phase of spin bowling.
7. To find out the phase wise all related biomechanical factor as a predictor of spin bowling as an accuracy of the bowl.

Limitations

1. Certain factors like diet, life style, habits, training protocols etc which might have had effect on the result of the study could not be controlled.
2. Non- availability of sophisticated instruments for measuring different parameters was considered as a limitation of the study.
3. No special motivational techniques were available during the data collection.
4. The videography was done in sagittal plane only.
5. The analyzing part was basically done in 2-D plane only.

Delimitations

1. The study was mainly delimited to under -19 women cricket players.
2. The subjects were taken from the different cricket divisions of Madhya Pradesh.
3. The study was delimited to thirty [N =30] off spin bowlers selected from different divisions of Madhya Pradesh.
4. The study was delimited to right-handed off spin bowlers only.
5. The study was further delimited to selected kinematic variables.
6. The study was delimited to 2-D motion analysis in six different phases which are as follows:
    - Run-up phase
    - Back foot phase
    - front foot
    - cradle position
    - release phase
    - follow-through
7. The study was further delimited to following biomechanical variables at different phases of spin bowling

Linear kinematic parameters

- Center of gravity of the body
- Speed of the ball
- Height of the ball in release phase

Angular kinematics parameters

- Position of head
- Angle at right and left shoulder joint
- Angle at right and left elbow joint
- Angle at right and left wrist
- Angle at right and left hip joint
- Angle at right and left knee joint
- Angle at right and left ankle

Hypotheses

1. It is hypothesized that there would be significant relationship between the selected kinematic variables with accuracy among the run-up phase of spin bowling in cricket.

2. It is hypothesized that there would be significant relationship between the selected kinematic variables with accuracy among the back-foot phase of spin bowling in cricket.

3. It it hypothesized that there would be significant relationship between the selected kinematic variables with accuracy among the front-foot phase of spin bowling in cricket.

4. It is hypothesized that there would be significant relationship between the selected kinematic variables with accuracy among the craddle delivery phase of spin bowling in cricket.

5. It is hypothesized that there would be significant relationship between the selected kinematic variables with accuracy among the release phase of spin bowling in cricket.

6. It is hypothesized that there would be significant relationship between the selected kinematic variables with accuracy among the follow-through phase of spin bowling in cricket.

7. It is also hypothesized that all selected linear and kinematic variables would have significant contribution while predicting the spin bowling for accuracy in case of each selected phase.

5 RESEARCH METHODOLOGY

For the purpose of the study minimum thirty [N= 30] Uner-19 women players of different divisions from Madhya Pradesh will be selected by using convenient purposive sampling technique. The training age of all the subjects was of minimum 5 years along with match experience of at least 2 years professionally at elite levels. All will be regular player with efficient spin bowling skill level. The purpose of the research will explain to all the subjects and subjects will be motivated to put their best during the test. The subjects those will be selected for the study are mentioned below-:

- Gwalior division cricket association (GDCA)
- Indore division cricket association (IDCA)
- Bhopal division cricket association (BDCA)
- Sagar division cricket association (SDCA)
- Reewa division cricket association (RDCA)

Independent Variables

1. **Linear kinematic variables selected for the purpose of the study at different phases are:**
    - Center of gravity of the body
    - Speed of the ball
    - Height of the ball at the time of release phase.
2. **Angular kinematic variables selected for the purpose of the study at different phases are:**

    - Position of head
    - Angle at right and left shoulder joint
    - Angle at right and left elbow joint
    - Angle at right and left wrist joint
    - Angle at right and left hip joint
    - Angle at right and left knee joint
    - Angle at right and left ankle.

Dependent variables

1. The accuracy of spin bowling was taken as the performance factor.

CRITERION MEASURE

In this study, off-spin bowling accuracy for each participant was the main criterion for evaluation. The performance in off-spin bowling was assessed based on skill execution and later measured using the Richard Aldworth Stretch Bowling Test (Stretch, 1984). This test showed a reliability coefficient of 0.85, a validity score of 0.81, and an objectivity measure of 0.78. The table below outlines the selected biomechanical variables, their corresponding tests, and the units of measurement for both the biomechanical factors and spin bowling accuracy performance of the bowlers.

Independent Variables

S no.	Variables	Test/equipment needed	Measuring units
1.	Height of ball at the time of release	Kinovea software	Meters
2.	Height of center of gravity in each phase	Kinovea software	Meters
3.	Speed of ball	Radar gun	Kilometer per hour
4.	Grip strength	Grip Dynamometer	Newton
5.	Length of fingers (index, middle)	Measuring tape	meters
6.	Angular kinematic variables	Kinovea software	Degree

Dependent Variables

S no.	Variables	Test/equipment needed
1.	Accuracy in spin bowling	Richard aldworth stretch bowling test

Procedure for Collection of Data

Accuracy performance of spin bowler

For this study, thirty right-handed off-spin bowlers will be selected. Each bowler will deliver ten legal deliveries, with a maximum score of ten points per ball, allowing a possible total score of 100. To ensure reliable data, bowlers will be instructed to bowl as if in a match setting. A standard cricket leather ball will be used throughout the test. A target area will be marked on the pitch using measuring tape, lime powder, nails, and rope, with the final markings outlined in string and lime powder. A scorer will record the scores on a prepared sheet. Bowlers will be allowed to choose between bowling over or around the wicket, with an overarm action required. Each bowler will bowl ten legal deliveries aimed at the target area. Deliveries that pitch or strike within the target's boundaries will receive higher scores. The cumulative score after ten deliveries will reflect the bowler’s accuracy, with higher scores indicating better precision.

Filming Protocol

The biomechanical analysis of the different phases of pace bowling in cricket, focusing on accuracy, will be conducted using videography. A Sony HDR CX-200 camera will be

employed, capturing footage at a frequency of 60 frames per second. The camera will be positioned on the sagittal plane, to the right-hand side of the subjects, as all participants will be right-handed. The study will focus on six key phases: the run-up, back-foot, front-foot, cradle position, release, and follow-through phases. Using the video footage, the researcher will generate stick figures to calculate the relevant biomechanical variables with the aid of Kinovea Software. Each subject will perform the skill ten times, and the trial with the highest score will be selected for detailed analysis.

Bowler's speed

In this study, the speed of the bowler will be measured using a Bushnell speed gun, as speed is an essential factor in influencing a bowler's accuracy. A bowler with a combination of high speed and accuracy can pose a significant challenge to the batsman. The researcher will stand at the opposite end of the crease, at the batting end, holding the Bushnell Speed Gun. As the bowler delivers the ball, the researcher will activate the trigger on the speed gun to record the speed, which will be noted in kilometers per hour (km/h).

Grip Strength

Grip strength will be measured using a grip dynamometer, with results recorded in Newtons, to assess the hand strength of U-19 female cricket players. This method will be chosen for its accuracy in evaluating grip force, which is crucial for off-spin bowlers. A stronger grip will enable bowlers to generate more spin, improve ball control, and reduce hand fatigue during long spells, thus enhancing performance and consistency in spin deliveries.

Measurement of Index and Middle Finger

The length of the index and middle fingers of U-19 female cricket players will be measured using a standard measuring tape with millimeter gradations. Players will extend their hand flat, palm up, and measurements will be taken from the base of the finger to the tip. Each measurement will be repeated twice for accuracy, and the average will be recorded.

Kinovea Software

Kinovea software will be used to analyze and record key biomechanical variables during the spin bowling action. It will track the height of the ball at the time of release, providing precise measurements in meters. Additionally, Kinovea will calculate the height of the center of gravity during each phase of the bowling action, again in meters, to assess the body's posture and alignment. The software will also record angular kinematic variables, such as joint angles, in degrees, allowing for a detailed analysis of the bowler's rotational movements. These measurements will contribute significantly to understanding the mechanics of spin bowling and its relationship with accuracy and efficiency.

6 STATISTICAL METHOD

SPSS software will be used for all statistical calculations. Mean, standard deviation, standard error of mean, kurtosis, skewness will be based as descriptive statistics and for predicting the contributing kinematic factors of spin bowling for accuracy at each phase, multiple regression model will be use at 0.05 level of significance.

7 EXPECTED OUTCOMES OF THE RESEARCH

1. The results of this study could serve as a significant factor in determining the key kinematic variables that contribute to the accuracy in spin bowling.

2. This research will be highly valuable as a model for talent identification, helping to nurture spin bowlers from the grassroots level in the country.

3. The study's findings will allow players to perform self-assessment, enabling them to evaluate and improve their own performance.

4. The study may also reveal the accuracy patterns of spin bowlers and identify the factors influencing them.

5. Spin bowlers can utilize the findings to recognize errors in each phase of their bowling action and make necessary corrections.

6. Coaches and physical education instructors will benefit greatly from this research, as it will assist them in refining the skills of aspiring bowlers under their guidance.

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